

decay products are long (35, 18, 18 cm) and lend themselves to accurate momentum measurement (188 ± 6 ; 127 ± 10 ; 103 ± 8 Mev/cy). The track of the τ meson is short and its momentum not directly measurable. Within experimental error the direction of the τ meson coincides with the vector sum of the momenta of the charged decay products, thus indicating the absence of neutral secondaries, in agreement with previous results. The τ meson is negative; in the only other case in which the sign of charge of a τ meson could be determined, it was found to be positive.¹ The specific ionization and curvature of the tracks are consistent with the assumption of π meson secondaries. On this assumption the energy release of the τ meson is 70 ± 3 Mev corresponding to a mass of $964 \pm 6 m_e$. The τ meson was not observed to originate in a nuclear event, thus there is no evidence here as to its mode of production.

* Supported in part by the joint program of the U. S. Office of Naval Research and the Atomic Energy Commission.

¹ R. B. Leighton and S. D. Wanlass, *Phys. Rev.* **86**, 426 (1952).

H7. Cross Section for the Production of Penetrating Cosmic-Ray Showers in Oxygen.* JAMES F. KENNEY AND VICTOR H. REGENER, *University of New Mexico*.—An experiment is being performed at Capillo Peak, New Mexico at an altitude of 2800 m to determine the cross section for penetrating shower production by neutral N rays in oxygen. The collision length for this event is measured in ethyl alcohol and in oxalic acid, and the oxygen cross section is obtained by the method of differences. The value of this cross section seems to fall fairly close to that predicted by the geometric nuclear

model. With further improvement of the statistical accuracy, the data from this experiment will be combined with those obtained from previous experiments with similar equipment using light and heavy water.¹ This will lead to an evaluation of the nuclear cross section for the production of penetrating showers in carbon, hydrogen, and deuterium.

* Supported in part by the National Science Foundation.

¹ G. W. Rollosos, *Phys. Rev.* **87**, 71 (1952); Froman, Kenney, and Regener, *Phys. Rev.* (to be published).

H8. Cross Section for Production of Penetrating Cosmic-Ray Showers. ROY THOMAS, *University of New Mexico*.—Highly energetic neutrons interacting with nuclei create showers of energetic protons, neutrons, π -mesons, etc. The usual theoretical approach is to assume that at very high energies the nucleons in a nucleus may be considered as free. One then calculates the cross section as a function of the nuclear radius and a collision mean-free path for an incident neutron in nuclear matter. The suggestion made in this paper is to consider the opposite view. We define an interaction volume directly proportional to the nuclear binding energy. Any incident neutron of sufficient energy which penetrates this interaction volume will initiate a penetrating shower. The cross section is proportional to the two-thirds power of the nuclear binding energy. Transparency of light nuclei to penetrating shower production thus follows with the introduction of only one parameter to be fitted to the experimental data. With any other theory one needs at least two parameters to explain the transparency of light nuclei.

THURSDAY AFTERNOON AT 4:15

Room 102, Mitchell Hall

(C. D. ANDERSON, presiding)

Contributed Papers

I1. Photoproduction of Positive Mesons from Hydrogen: Magnetic Spectrometer Method. R. L. WALKER, J. G. TEASDALE, AND V. Z. PETERSON, *California Institute of Technology*.—The differential cross section for photoproduction of positive pions in hydrogen has been measured at angles from 40° to 150° in the center-of-mass system, for photon energies from 220 to 475 Mev. An attempt will be made to extend this range of angles. Mesons produced by 500-Mev bremsstrahlung in a high-pressure gas target are analyzed by a large magnet with wedge-shaped pole pieces and counted by two large liquid scintillation counters in coincidence, placed at the focal point of the magnet. A typical arrangement of counters and magnet accepts mesons emitted in a solid angle of 0.01 steradians with a momentum resolution of nine percent. This corresponds to a spread in incident photon energies of 10 Mev in the low-energy region and 50 Mev at the high-energy end. Range measurements of the analyzed particles show that most of them are π mesons but that some μ mesons are counted as expected. The flight path of the mesons is long, and corrections for π - μ decay amount to a factor 1.2 to 1.8, depending on the meson energy. Results obtained so far are reported in the third abstract of this series.

I2. Angular Distribution of Positive Photomesons from Hydrogen: Counter Telescope Method. A. V. TOLLESTRUP, J. C. KECK, AND R. M. WORLOCK, *California Institute of Technology*.—The angular distribution and excitation curve for the process $\gamma + p \rightarrow \pi^+ + n$ have been obtained for gamma-ray energies between 225 and 475 Mev. This experiment was done

simultaneously with the accompanying magnetic spectrometer experiment, but it is independent of that experiment except for the common beam monitoring equipment. The mesons from the high-pressure, low-temperature hydrogen target were identified by measuring their ionization for a fixed residual range with a scintillation counter telescope consisting of 3 counters in coincidence and a fourth in anticoincidence. The meson energy, as deduced from its range in copper, and its angle determine the photon energy. The energy resolution of the counter telescope was determined by the amount of absorber between the last two counters. This was chosen so that the spread of meson energies accepted was 10 Mev which corresponded typically to a 20-Mev spread in photon energy. The background corrections due to mesons from the walls of the hydrogen target and to accidental coincidences in the telescope are about 10 percent, and the statistical errors are in general about 5 percent. Excitation curves were run at angles corresponding to angles of 50° , 70° , 90° , 110° , 130° , and 150° in the c.m. system, and from smoothed curves the angular distribution was obtained. The results are discussed in the last paper of this series.

I3. Photoproduction of Positive Mesons from Hydrogen: Results. R. F. BACHER, J. C. KECK, V. Z. PETERSON, J. G. TEASDALE, A. V. TOLLESTRUP, R. L. WALKER, AND R. M. WORLOCK, *California Institute of Technology*.—The center-of-mass differential cross section for photoproduction of positive pions from hydrogen has been measured by the methods described in the two previous abstracts, in the angular range 40° to 150° ,

for photons from 220 to 475 Mev. (Photon energies refer to the Laboratory System.) Results obtained by the two methods are in essential agreement. At 90° , $d\sigma/d\omega$ has a maximum of 2.7×10^{-29} cm²/sterad near 280 Mev and falls by a factor 5 at 450 Mev. The maximum in the excitation curve is even more pronounced at larger angles, but less pronounced at smaller ones. At 40° (c.m.) the peak occurs near 350 Mev, and at 450 Mev the cross section has decreased only to 0.7 the peak value. Angular distributions in the center-of-mass system show a marked asymmetry about 90° , which changes character from low energy to high. Below 325 Mev, there is a backward maximum, whereas above 375 Mev, there is a forward maximum. The total cross section reaches a maximum near 290 Mev and decreases by about a factor 3 at 450 Mev. The results below 300 Mev agree with the data already reported from Berkeley and Cornell.

14. Yield of Mo⁹⁹ from Fission of U²³⁵ and U²³⁸.† JAMES TERRELL, W. E. SCOTT,* J. S. GILMORE, AND C. O. MINKINEN, *University of California, Los Alamos Scientific Laboratory*.—A double fission chamber was used to measure the fissions produced in one-inch diameter, 25-gram disks of U²³⁵ and normal uranium. Thin foils of the same material, mounted on either side of the disks, were fission counted during irradiation. Corrections were applied for counting losses and the effects of fission-produced and scattered neutrons from the disks. Fast neutrons were produced by P-T, D-D, and D-T reactions; the thermal neutron source was the Los Alamos Homogeneous Reactor. The yield of Mo⁹⁹ was determined by chemical separation of molybdenum from the disks, followed by absolute beta counting. Absolute calibration was done with the aid of John P. Balagna of this laboratory. Results obtained so far (Mo⁹⁹ atoms per fission) are tabulated here, with estimated standard deviations. The thermal value

	Thermal	0.95	1.55	4.85	14.2	(Mev)
U ²³⁵	6.14 ± 0.16	6.10 ± 0.16		5.45 ± 0.16		(percent)
U			6.19 ± 0.15	6.45 ± 0.16	5.68 ± 0.14	(percent)

and the decrease with increasing energy are consistent with other determinations.¹

† Work done under the auspices of the U. S. Atomic Energy Commission.
* Major, United States Air Force, now at Kirtland Air Force Base, New Mexico.

¹ *Radiochemical Studies: The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1951), National Nuclear Energy Series, Div. IV, Vol. 9.

15. The Energy Distribution of Slowed Fission Fragments.* J. A. NORTROP AND J. E. BROLLEY, JR., *University of California, Los Alamos Scientific Laboratory*.—A conventional gridded ion chamber has been used to measure the energy distribution of fission fragments slowed by a UO₂ absorber. A 20μ g/cm² layer of U²³⁵O₂ 2 in. in diameter vacuum evaporated on a 0.030-in. tantalum backing and placed in a beam of thermal neutrons from the Los Alamos Homogeneous Reactor provided the source of fission fragments. These were slowed by a uniform layer of U²³⁸O₂ evaporated directly over the first. A series of six such foils, each having a 20μ g/cm² U²³⁵O₂ base layer, but U²³⁸O₂ layers varying from 0 to 1 mg/cm², were mounted on a wheel inside the ion chamber in such a way that they could be successively rotated into the neutron beam. The high uniformity of these foils made it possible to obtain fission curves in which the ratio of the light peak to the valley between is 14:1, even after slowing the fragments in the UO₂. There is some evidence for complex structure on the high-energy side of the heavy particle peak of the unsloved fragments. Preliminary results for the initial energy loss of fission fragments in UO₂ is 0.020 Mev-cm²/μ g (light fragment), 0.017 Mev-cm²/μ g (heavy fragment).

* Work done under the auspices of the U. S. Atomic Energy Commission.

16. Velocity Distributions of Slowed Fission Fragments. H. W. SCHMITT AND R. B. LEACHMAN, *University of California, Los Alamos Scientific Laboratory*.—The velocity distributions of slowed fission fragments have been measured by a method similar to that used by Leachman¹ in the determination of the velocity distributions of fission fragments from the thermal fission of U²³³, U²³⁵, and Pu²³⁹. In our measurements, fragments from the thermal fission of U²³⁵ are slowed by perpendicular passage through thin nickel or aluminum absorbers as follows: 1.1 mg/cm² Ni, 1.1 mg/cm² Al, 1.4 mg/cm² Al. The slowed-fragment velocity distributions show a definite irregularity in the heavy peak but a less pronounced irregularity in the light peak. This difference in irregularities is at least partially explained by the better resolution in the measurements of the heavy fragment groups. These irregularities are in agreement with the fine structure in the mass yield of fission as found by Glendenin *et al.*² The fact that the irregularities are more prominent in the distributions obtained with more absorbing foils can be explained in terms of shell effects and processes of energy loss of fission fragments in matter.

¹ R. B. Leachman, *Phys. Rev.* **87**, 444 (1952).

² Glendenin, Steinberg, Inghram, and Hess, *Phys. Rev.* **84**, 860 (1951).

THURSDAY EVENING AT 8:00

Student Union Ballroom

(V. H. REGENER, presiding)

Public Lecture

J1. Developments in High-Energy Physics. E. FERMI, *University of Chicago*.